Sediment Delivery from Forest Road-Stream Crossing Approaches in the Virginia Piedmont Region, USA

Kristopher Brown

VirginiaTech

Virginia WATER RESOURCES Research Center

Kevin McGuire, Mike Aust
Cully Hession, Andy Dolloff

Forest Resources & Environmental Conservation at Virginia Tech

VIRGINIA DEPARTMENT OF FORESTRY

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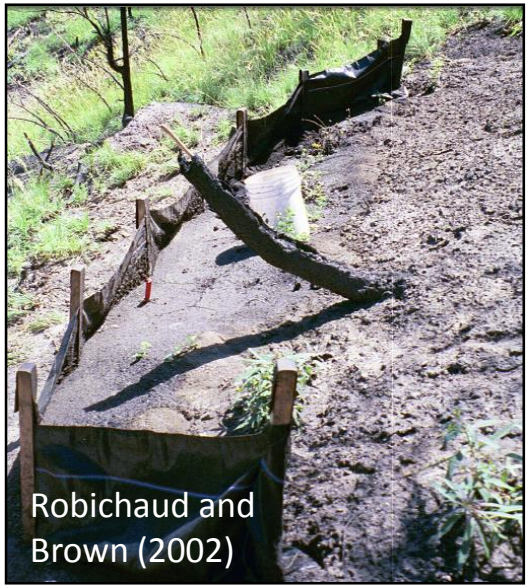
Forest roads at stream crossings

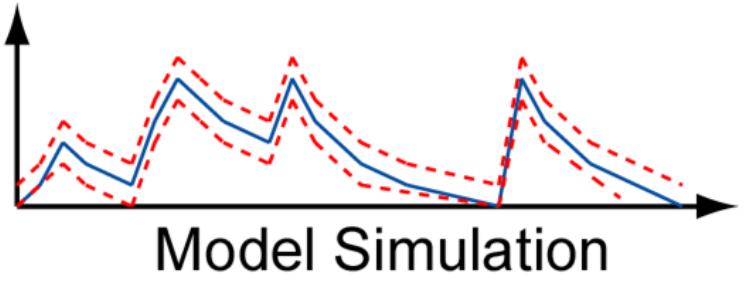
- Sediment delivery potential is greatest at the road-stream interface
- Issue has sparked legislative debates about CWA permits and NPSP status of forest roads

Need to document the efficacy of BMPs to reduce sediment delivery from roads… **How?**

Turton et al. (2009)

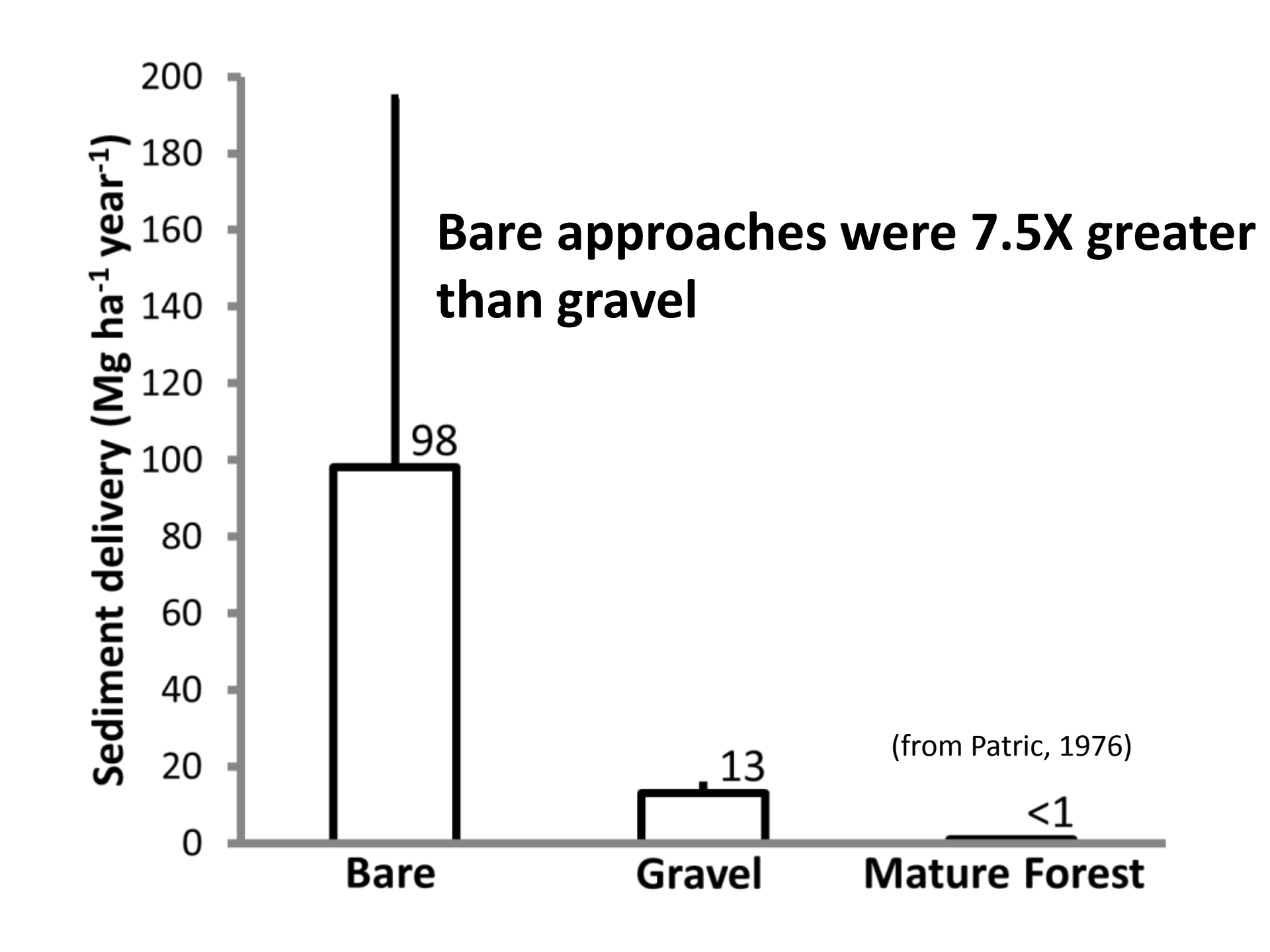

Robichaud and Brown (2002)

FSWEPP



Field study 1: Sediment trapping

- **Objective:** Quantify annual sediment delivery rates for bare and graveled stream crossing approaches


Sediment delivery (Mg ha-1 year-1)
200
180
160
140
120
100
80
60
40
20
0
98
13
<1
Bare
Gravel
Mature Forest
Bare approaches were 7.5X greater than gravel
(from Patric, 1976)

Problem road segments

- Surface runoff traveled 75 and 130 m between the nearest water control structure and the silt fence
- 90 to 100% bare soil conditions throughout the year

Field data to parameterize soil erosion models

- USLE-forest: A = RKLSCP
- C sub-factors were evaluated 3 times from Aug. 2011 to Aug. 2012.
- Erosion predictions were averaged by site to produce annual estimates of sediment delivery (Mg ha^{-1} yr^{-1}) (N=9).

Building WEPP hillslope profiles

Inputs

Climate

Soil

Slope

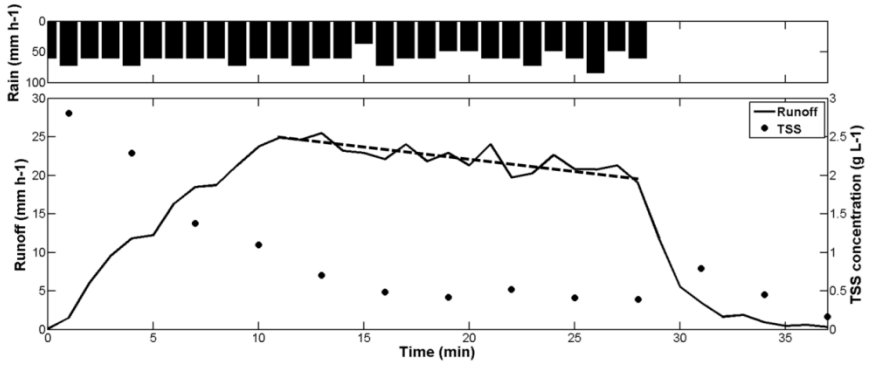
Management

Runoff

Effective hydraulic conductivity, initial saturation

Sediment yield

Interrill and rill erodibility, critical shear, initial rill width, initial surface roughness



Site	Measured erosion ($Mg\ ha^{-1}\ year^{-1}$)	Modeled erosion			
		USLE-forest		WEPP	
		Erosion estimate ($Mg\ ha^{-1}\ year^{-1}$)	Percent deviation (modeled v. measured)	Erosion estimate ($Mg\ ha^{-1}\ year^{-1}$)	Percent deviation (modeled v. measured)
Bare 4	287	44.8	-84	245.4	-14
Bare 5	85	29.1	-66	124.4	46
Bare 3	41	51.2	25	6.1	-85
Bare 1	41	66.2	61	3.1	-92
Bare 2	34	43.1	27	1.6	-95
Gravel 2	16	0.3	-98	0.0	-100
Gravel 1	13	0.7	-95	0.0	-100
Gravel 4	12	2.5	-80	0.0	-100
Gravel 3	10	0.3	-97	0.0	-100

Model predictions were not accurate.

However, models predicted substantial sediment delivery rates for “problem” roads.

WEPP performed better than USLE-forest in ranking the problem road approaches

Field study 1 conclusions

- Legacy roads may require additional measures to protect water quality upon reopening
- Findings support contemporary BMP recommendations to:
  - gravel the entire stream-crossing approach
  - place a water control structure at least 7.6 m before the stream crossing
- Despite poor accuracy, USLE-Forest and WEPP can estimate BMP effectiveness

Field study 2: Rainfall simulation

- **Objective:** Quantify event-based surface runoff and sediment yield for reopened approaches with different proportions of gravel cover

No gravel

10-19% cover

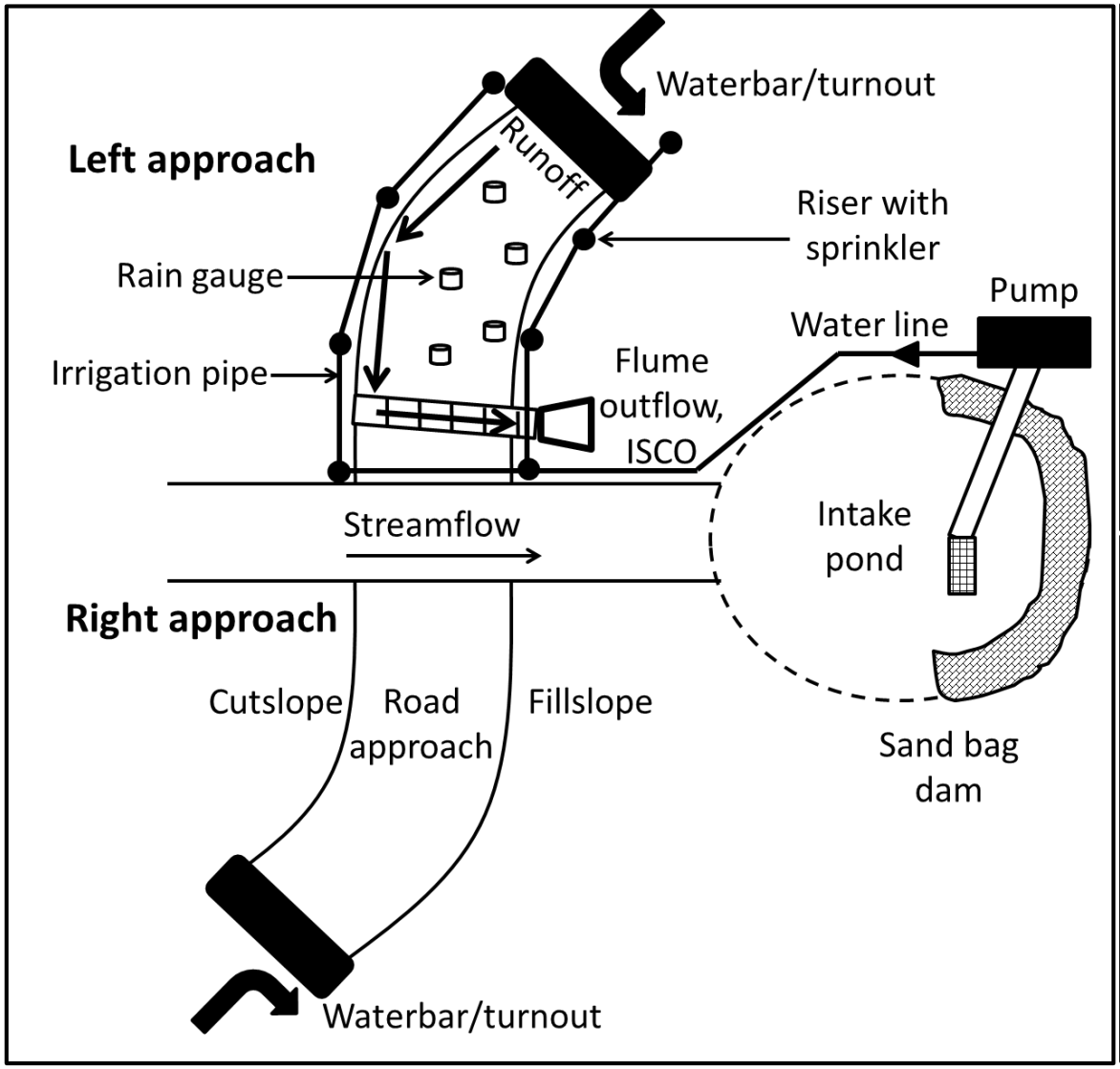
Low gravel

34-60% cover

High gravel

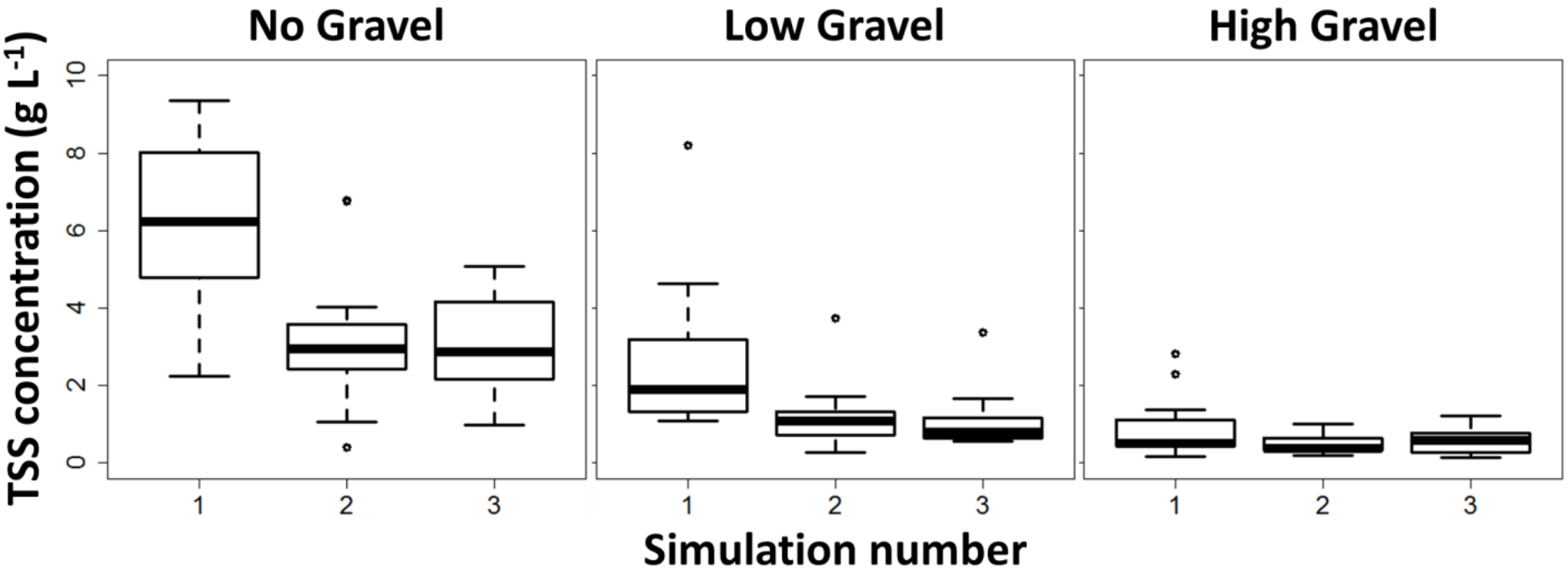
50-99% cover

Rainfall simulation

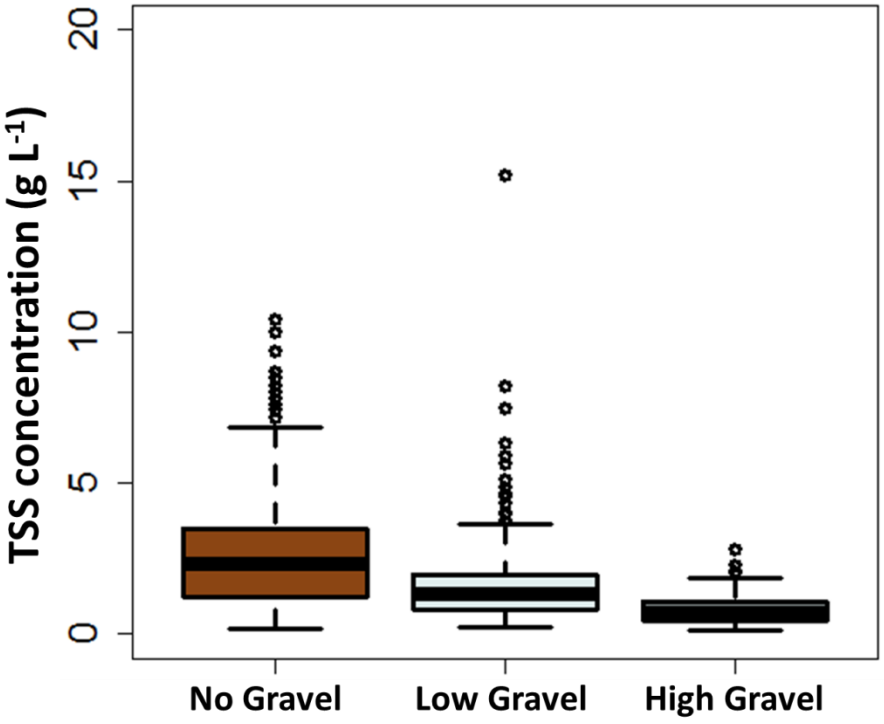


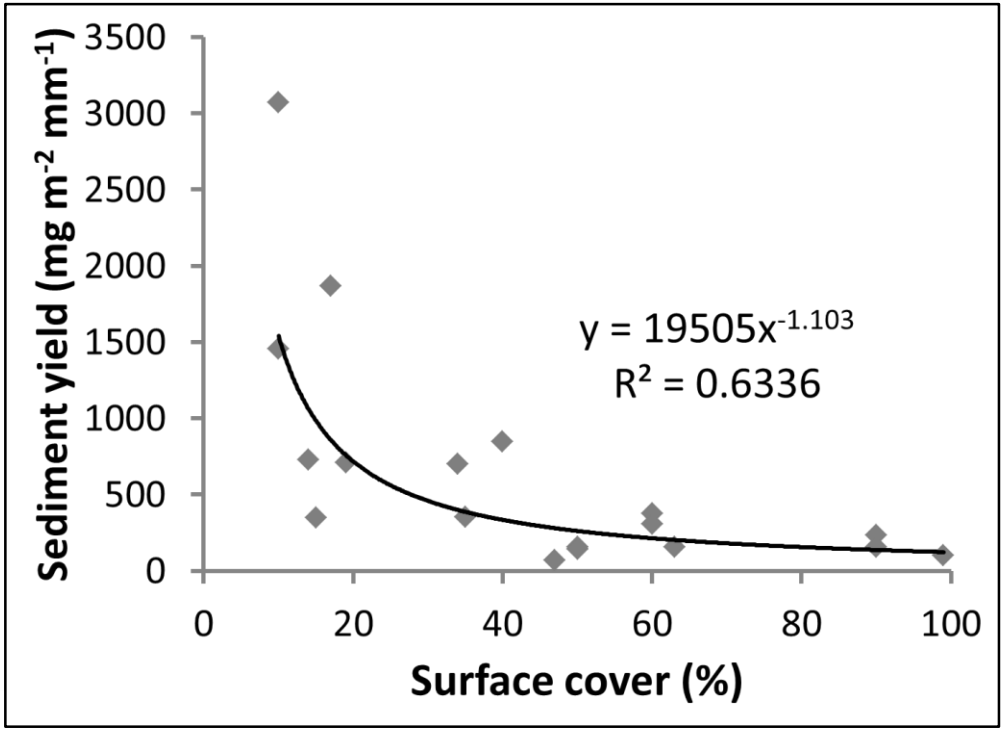
Sediment yield was reduced by:

- Successive rainfall events
- Increasing surface cover



Sediment-reduction efficacy of gravel





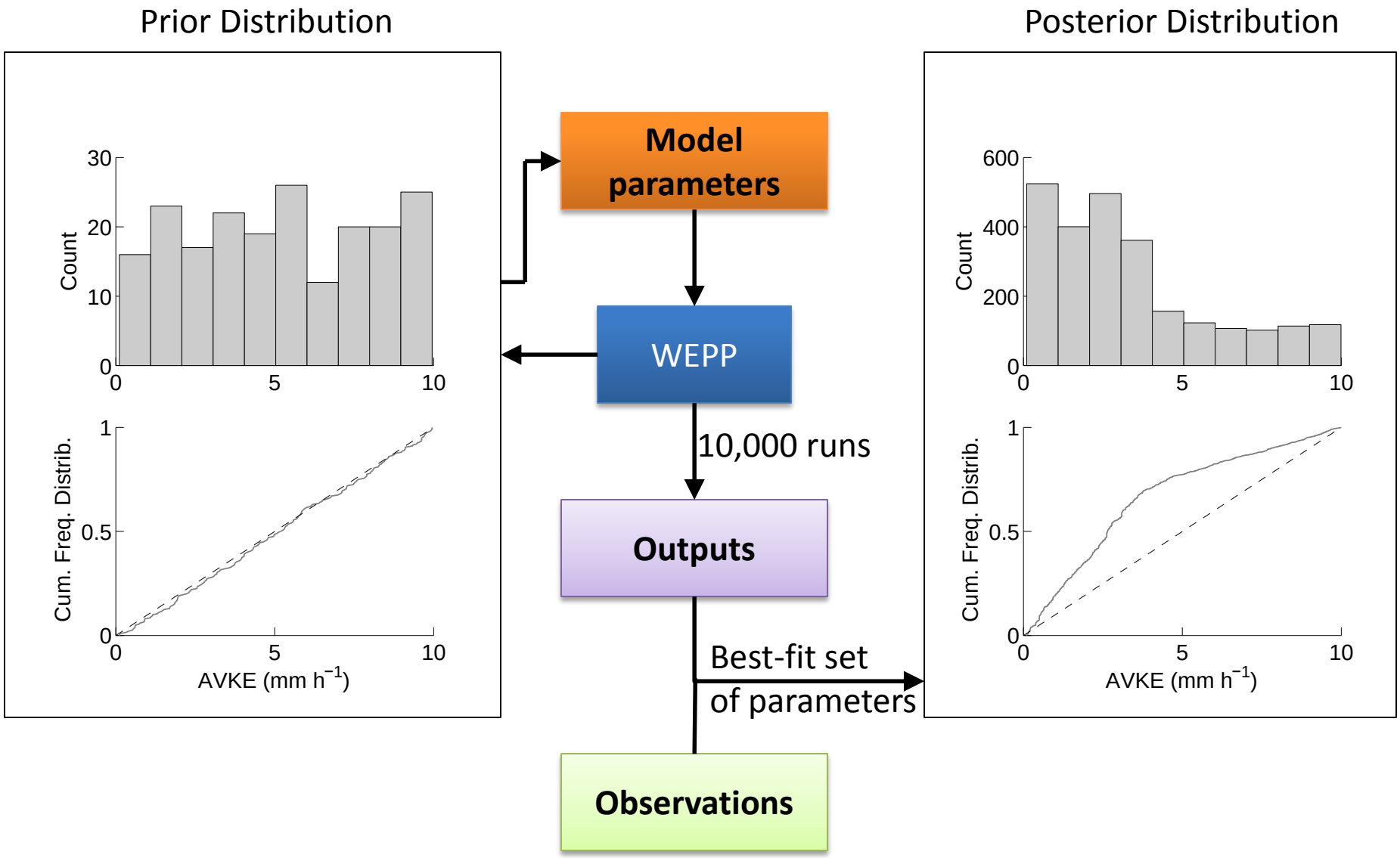
Median TSS concentration for the No Gravel treatment was 2.6 and 3.5X greater than that of the Low Gravel and High Gravel treatments, respectively

BMP effectiveness is site-specific.

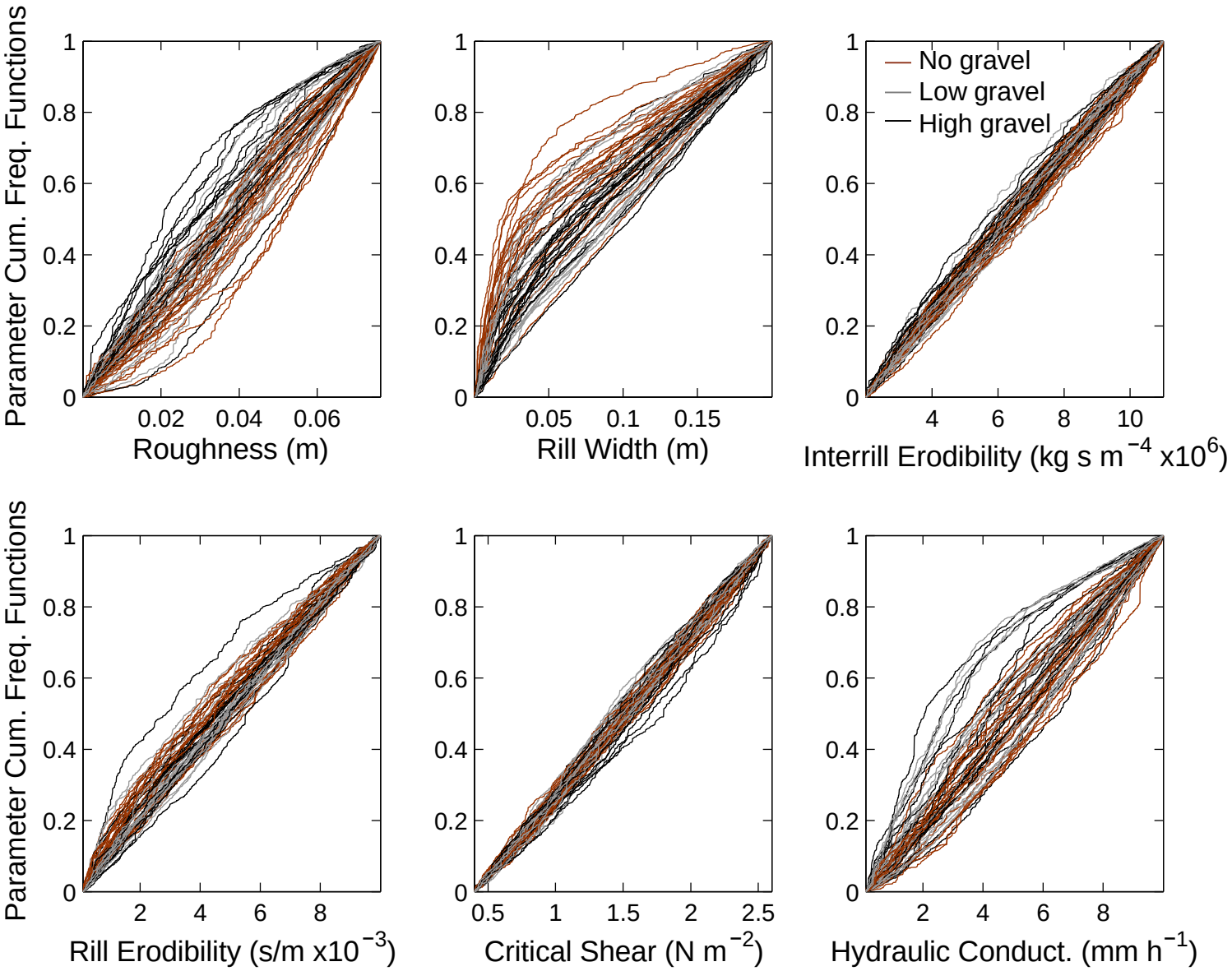
However, sediment yield decreased with successive gravel treatments in 4 of 6 sites.

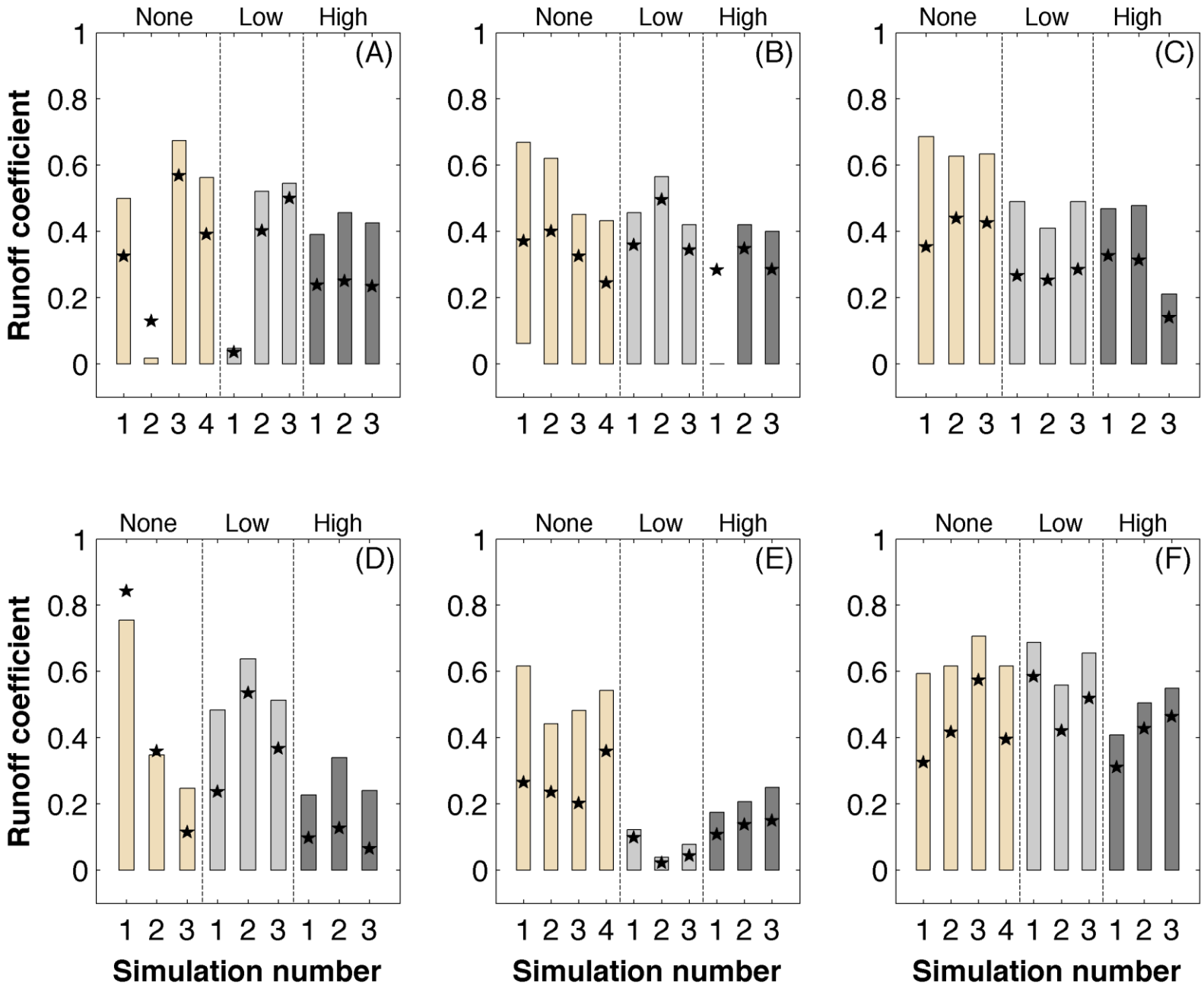
Site	Sediment yield ($mg\ m^{-2}\ mm^{-1}$)			Gravel cost ($)		Sediment yield difference from No Gravel (%)	
	No Gravel	Low Gravel	High Gravel	Low Gravel	High Gravel	Low Gravel	High Gravel
1	1458	351	233	100.96	201.92	-76	-84
2	350	850	158	81.42	162.84	143	-55
3	1867	374	158	104.22	208.44	-80	-92
4	3072	699	144	81.42	162.84	-77	-95
5	728	71	156	94.45	188.90	-90	-79
6	709	309	100	84.68	169.36	-56	-86

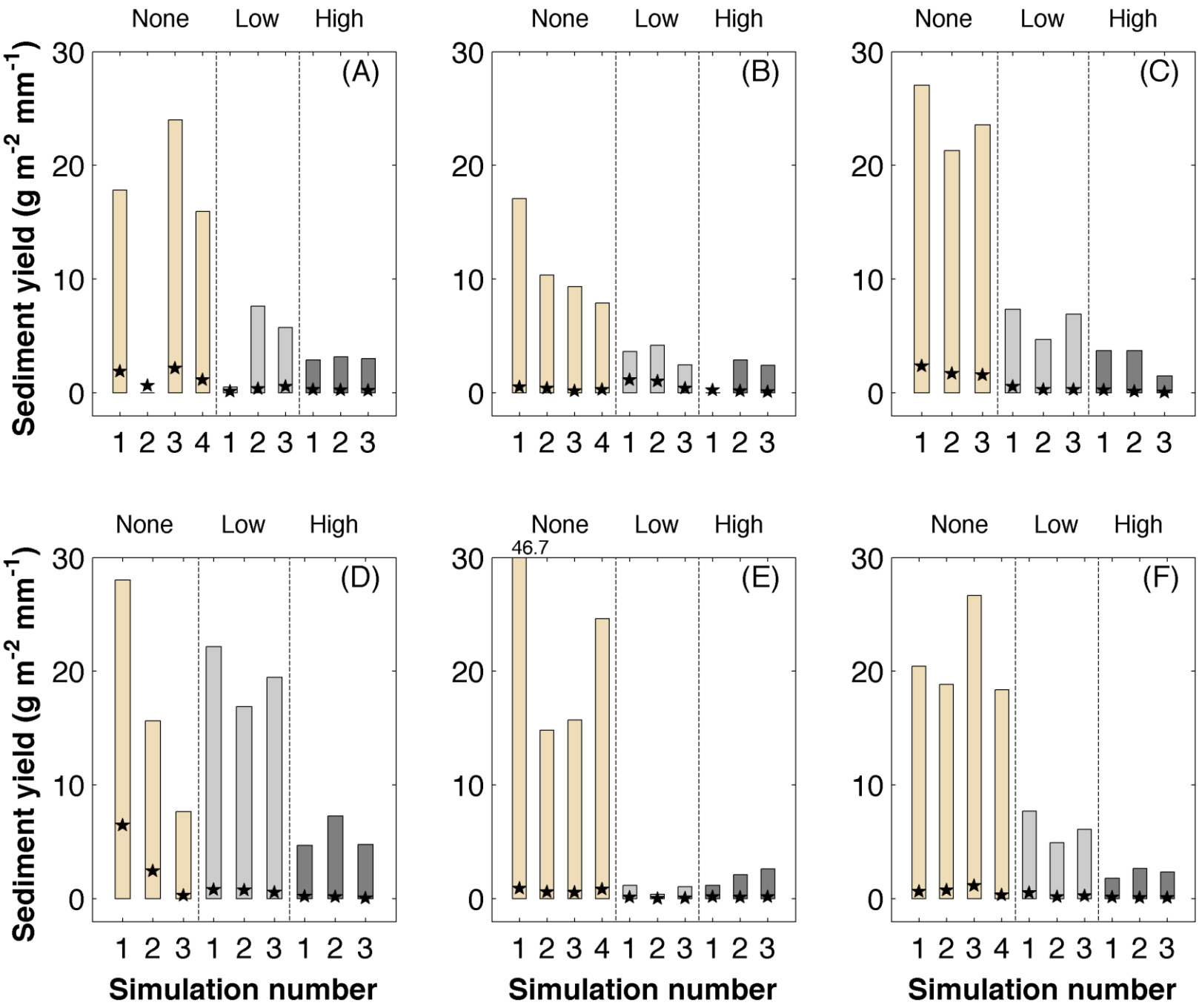
Parameter identifiability & sensitivity



Complete set of posterior distributions for all sites, all reps: 58 rainfall simulations




None
Low
High
(A)
(B)
(C)
(D)
(E)
(F)
Runoff coefficient
Simulation number
0
0.2
0.4
0.6
0.8
1
1 2 3 4 1 2 3 1 2 3


None
Low
High
(A)
(B)
(C)
(D)
(E)
(F)
46.7
Sediment yield (g m-2 mm-1)
Simulation number
0
10
20
30
1 2 3 4 1 2 3 1 2 3

WEPP evaluation conclusions

- While prediction uncertainty was large, runoff patterns were generally captured.
- Sediment yield predictions showed clear differences among road surface treatments.
- Little guidance available on reasonable parameter values and some parameters are not sensitive which leads to high uncertainty

Implications

- WEPP can be useful for estimating BMP effectiveness…
  - Predictions captured the ranking of BMP intensity (i.e., no gravel to high gravel)

- BUT prediction uncertainty is large and should be considered in management and planning.

- Sediment predictions from models should ALWAYS include uncertainty, e.g., 10.3 t/a/y **(±2.3)**

Overall conclusions

- Road planning is the most important BMP
- Gravel surfacing and adequate water control structures can improve problem roads
- USLE is better suited for forest managers
- Need more field studies for improved *a priori* parameter ranges


Questions?